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Title	The SEAFDEC Aquaculture Department at 21: R&D for sustainable aquaculture
Author(s)	Bagarinao, T. U.; Flores, Efren Ed C.
Citation	Bagarinao T.U, Flores EEC. (1995). The SEAFDEC Aquaculture Department at 21: R&D for sustainable aquaculture. In: T.U. Bagarinao & E.E.C. Flores (eds.) Towards Sustainable Aquaculture in Southeast Asia and Japan. (pp. 227-249). Iloilo, Philippines: SEAFDEC Aquaculture Department.
Issue Date	1995
URL	http://hdl.handle.net/10862/121

This document is downloaded at: 2013-07-02 01:03:07 CST

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The SEAFDEC Aquaculture Department at 21: R&D for Sustainable Aquaculture

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Bagarinao TU, Flores EEC. 1995. The SEAFDEC Aquaculture Department at 21: R&D for sustainable aquaculture, pp. 227-249. In: Bagarinao TU, Flores EEC (eds) Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines.

Abstract

This paper reviews the research output of the SEAFDEC Aquaculture Department (AQD) over the past 21 years of its existence. These realized studies are compared with the priority problem areas recommended for research by international or regional seminar-workshops convened by AQD in 1983, 1987, 1991 and 1994. Between 1976 and 1994, AQD researchers produced 554 publications, including 274 in journals indexed by the Institute for Scientific Information, 122 in other journals, and 158 in conference proceedings. Another 82 publications from work done outside AQD were authored or co-authored by AQD researchers, mostly during their graduate programs. In addition, AQD published 21 extension manuals and 14 technical reports and monographs by AQD researchers, and co-published two other monographs by non-AQD researchers. AQD's major contributions have been the technologies for tiger shrimp seed production, grow-out culture, feeds, and disease control; milkfish seed production and feeds; rabbitfish seed production; and tilapia feeds and strain selection. Communication and two-way feedback among AQD researchers and representatives of the aquaculture industry and the SEAFDEC Member Countries must be improved to fine-tune AQD research. In the late 1980s, AQD started redirecting some of its research towards environmental problems in aquaculture. Much of the near future will be spent implementing research imperatives in sustainable and responsible aquaculture.

Introduction

After two decades, it is time for the SEAFDEC Aquaculture Department (AQD) to take stock and evaluate the past and present, and stride into the 21st century with greater resolve and a clearer focus: the continued promotion of aquaculture within the context of sustainable development. Various authors (GESAMP 1991, Pullin 1993, Csavas 1995, McManus 1995, de la Cruz 1995, Phillips 1995) have made important recommendations regarding how sustainable and responsible aquaculture may be achieved, and Chua (1993) has laid down some policy guidelines

and management strategies for aquaculture within the framework of integrated coastal zone (and watershed) management.

Now more than ever, it is important to improve strategic planning in aquaculture and to give more attention to asking the right questions to be attacked through research (Davy 1991). One approach towards this goal is a historical review of research and development (in a given sector, or a country, or by an institution), as there often is value in looking back and trying to learn from past experiences. The evolution of research systems in relation to development objectives, particularly better definition at the starting point of research, must be given the attention that it deserves in aquaculture and fisheries.

AQD's research and other operations as it turned a decade old were reviewed by Lacanilao (1983). Another opportunity for a historical review presents itself now, after ADSEA '94, the third Seminar-Workshop on Aquaculture Development in Southeast Asia and 21 years into AQD's existence. ADSEA was conceived about a decade ago as a means to assess the contribution of the SEAFDEC Aquaculture Department to the development of the aquaculture industry in southeast Asia. ADSEA meetings were convened by AQD in 1987, 1991, and 1994. These were attended by representatives of SEAFDEC Member Countries, the academe, the private sector, and government agencies. ADSEA '94 was also attended by representatives from Vietnam and Indonesia, and ADSEA '91 and '94 by invited scientists who presented reviews of special topics. The constraints in aquaculture in different countries in the region were identified during the workshops, then the country representatives prioritized the species and problem areas for AQD research. Thus, these meetings ended with lists of recommendations and priorities, which became the basis of the three-year plans of AQD.

Before ADSEA '87, AQD had also convened the International Milkfish Workshop Conference in May 1976, the Second International Milkfish Aquaculture Conference in October 1983 (Juario et al. 1984), and the First International Conference on the Culture of Penaeid Prawns/Shrimps in December 1984 (Taki et al. 1985), all in Iloilo. Later seminar-workshops were held to discuss aquaculture manpower training (Villegas et al. 1993), and research and development in fish breeding and seed production, and in feeds and feeding. In addition to these formal meetings, AQD holds yearly round-table dialogues with aquaculturists, researchers, and government administrators in the Philippines. The stated aim is always, in effect, to review and then fine-tune AQD's research.

It is thus of academic and practical interest to see how the research output of AQD scientists has matched the needs of the aquaculture industry as identified during the various meetings. This paper shows the relation between recommended and realized research at AQD and the resulting contribution of AQD to aquaculture development. The result of the analysis may be used to decide whether AQD has lived up to its research mandate. This paper also spells out some of the new directions that AQD has taken or will take in support of sustainable aquaculture.

AQD's Research Output

Since its establishment 21 years ago, AQD has become a well recognized aquaculture research institution, not only in the region but the world over. A large number of studies were proposed (e.g., 754 studies between 1974 and 1982) but the results of those from AQD's earlier

years went unpublished, or became in-house reports with no external peer review (Lacanilao 1983). A better measure of AQD's research accomplishment is not the number of proposed studies but the number of publications from completed research. Between 1976 and 1994, AQD researchers produced 554 publications, including 274 in journals indexed by the Institute for Scientific Information (ISI), 122 in other journals, and 158 in conference proceedings. Another 82 publications from work done outside AQD were authored or co-authored by AQD researchers, mostly during their graduate (theses) programs. In addition, AQD published 21 extension manuals and 14 technical reports and monographs by AQD researchers. AQD also co-published key monographs on the milkfish industry (Librero 1976, Smith 1981).

The 554 publications were tallied by year, aquaculture commodity, and research topics. Figure 1 shows the breakdown of these publications by year, together with the subset of papers published in ISI-covered journals. The difference between the two curves represents the papers in other journals and in proceedings. A peak number of proceedings papers were produced in 1986 due to the First Asian Fisheries Forum held in Manila, Philippines in 1985 (Maclean et al. 1986). The publications have slowly increased over AQD's lifetime as our scientists 'matured' and more research studies were completed. The sharp increase in ISI-covered papers in 1990 was due to a rethinking (with incentive) among AQD researchers: that stringent peer review and verification of research results among scientists is a necessary first step for the development of aquaculture technology. Publication of scientific papers in ISI-covered journals is preferable over the production of 'grey literature' in conference proceedings and in-house reports (Bagarinao 1994a).

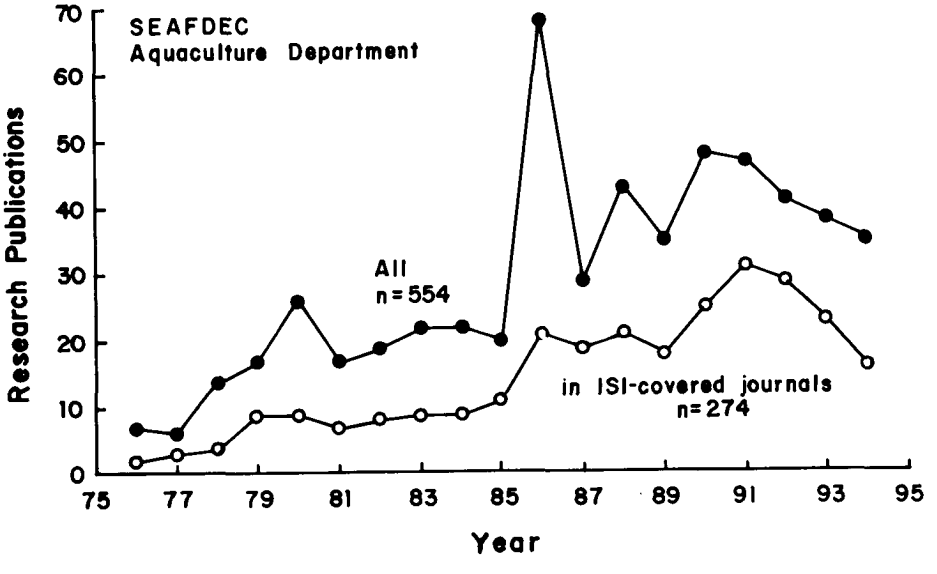

Fig. 1. Number of AQD publications from 1976 to 1994.

The tally includes research conducted at or by AQD in part or whole. The researchers of the SEAFDEC Aquaculture Department are mainly Philippine nationals, mostly with M.Sc. degrees. Others affiliated with AQD include some Japanese researchers assigned to AQD by the Japan International Cooperation Agency, or who hosted AQD researchers in their laboratories in Japan. Several others were Europeans or Americans who collaborated with AQD researchers on some AQD-based project.

The number of publishing AQD scientists (Ph.D., M.Sc, or B.Sc. with publications) increased from five in 1976 to 47 in 1986 and varied from 25 to 35 in 1987-94. The publishing scientists produced an average of 1.3 papers a year. The number of AQD researchers increased from 4 in 1974 to 83 in 1982 and has varied between 57 and 68 during the last seven years. The annual publication rate varied from 0.18 to 0.92 during 1976-94 when all researchers were considered.

So, AQD is reasonably good at producing scientific papers. AQD's research is generally of the 'applied' type, mostly targeted at developing aquaculture technologies, such as in breeding, hatchery, nursery, grow-out, feeds, and health management. But, even applied research does not necessarily translate to technology, much less to aquaculture production. The impact of AQD's scientific papers in terms of aquaculture production is difficult to show (and the assessment of the economic benefits of AQD's research and development is not the purpose of this paper). Indeed, research benefits may be difficult to prove (Nature 359: 173-174, 1992) and yet the perils of accountability in science are only too real (Aiken 1992). What can be shown is whether AQD's scientific papers addressed the problems brought to AQD's attention during the various seminar-workshops such as ADSEA.

How Relevant Were the Studies?

By 'relevant' we mean done at the right time in answer to identified needs. Ideally, research should also be 'appropriate,' meaning done to develop technologies that are environment-friendly, socially equitable, culturally sensitive, and sustainable. To get some idea of relevance, the topics of the publications were compared with the lists of recommended research topics and priority species from the Second International Milkfish Aquaculture Conference (Juario et al. 1984), ADSEA '87 (Juario and Benitez 1988), and ADSEA '91 (Lacanilao et al. 1994). Taki et al. (1985) did not produce a list of recommendations. These topics were tabulated by year periods preceding and following the major conferences. From proposal to published scientific paper may take just 1-2 years but usually longer; this lag time must be borne in mind when comparing recommended versus realized research.

The First Annual Report 1973 defined AQD's research activities, which were restated in the 1981 Annual Report to include:

- Production of adequate supply of quality seeds
- Improvement of culture techniques including water quality management practices
- Formulation of low-cost feeds and propagation of natural food organisms
- Control of pests, predators, and diseases
- Improvement in the design of aquaculture facilities
- Socio-economics of aquaculture
- Aquatic pollution in relation to aquaculture

AQD's research started with programs on crustaceans, milkfish, and Seafarming (mollusks). Research then moved on to tilapia and other freshwater fishes, to herbivorous and carnivorous marine fishes, and to seaweeds. It must be noted that since the beginning, environmental problems related to aquaculture were part of the research mandate of AQD.

Research on Shrimps

The research program for tiger shrimp started with induced spawning for seed production in the hatchery, with concurrent studies on the biology and ecology of various life stages in the wild (Santiago 1977, Primavera 1978, Motoh 1985). Before the 1984 shrimp conference, intense research was already underway in broodstock development, hatchery techniques, grow-out in ponds, feed development, and in diseases and chemical use (Table 1). Work on broodstock, feeds, and diseases intensified following the shrimp conference and the ADSEA meetings.

ADSEA '87 prioritized tiger shrimp as No. 1 and called for the development of: (1) captive broodstock, (2) economically feasible diets for grow-out, broodstock, and larvae, (3) refined hatchery and nursery techniques, (4) techniques for disease prevention and control in the hatchery, (5) water management methods for ponds. All these needs, except (5) were addressed by AQD's research (Table 1). The technologies follow often slowly from the research.

Table 1. The number of publications by AQD researchers on various research topics concerning tiger shrimp.

Research topics	Number of papers					Total
	1976-1980	1981-1984	1985-1987	1988-1991	1992-1994	
Broodstock management	9	3	3	8	5	28
Spawning	3	1				4
Hatchery	2	4		4		10
Larval development	2					2
Nursery			1		1	2
Grow-out	3	3	3	5	3	17
Feeding habits	1	2				3
Nutrient requirements		2	3	4	1	10
Digestive physiology			3	1	1	5
Feed development	5	3	2	6	1	17
Feed storage				1	2	3
Diseases	4		2	6	1	13
Tolerance limits	1		3	2	4	10
Chemical use	2	1	3	3	2	11
Biology, tagging	1			1	1	3
Environment				1	4	5
Total	33	19	23	42	26	143

ADSEA '91 prioritized tiger shrimp as No. 2 and called for more specific research on: (1) restocking of juveniles or adult shrimps in identified sanctuaries, (2) comparison of the performance of larvae from wild spawners, and from ablated and unablated broodstock, (3) a standard set of criteria for fry quality, (4) genetic selection, (5) health management, and (7) ecological effects of intensive shrimp culture. An ongoing Ph.D. thesis aims to identify suitable natural habitats for restocking or searanching of tiger shrimps (JH Primavera, personal communication). Captive broodstock and larval quality are being studied, but genetic selection has not been done. AQD researchers have continually monitored and studied new diseases in shrimp hatcheries and ponds (Table 1). Health management has become more crucial in recent years, and AQD has properly emphasized preventive measures such as sanitation rather than chemotherapy, which is often hazardous to shrimp, farm workers, and consumers. Primavera (1993 and earlier papers) has documented the ecological effects of intensive shrimp farming in both scientific and layman media.

ADSEA '94 has again placed tiger shrimp No. 1 priority for AQD research (see Priorities and Recommendations, page 251). The recommended research topics are basically the same as in ADSEA '91, but with additional imperatives to understand and manage the environment (including soil, water, carrying capacity, feed and chemical inputs, and effluents) within and surrounding the culture ponds. A clear call has also been made for aqua-silviculture technology to rehabilitate abandoned ponds. If these environmental studies could be carried out by AQD, they would be great leaps forward in making shrimp culture sustainable.

Research on Other Crustaceans

Even before the tiger shrimp industry became a roller-coaster enterprise, both government and the private sector called for the development of culture methods for other shrimps and other crustaceans of export potential. AQD researchers did some work on other *Penaeus* shrimps, on the mudcrab *Scylla serrata,* and the freshwater prawn *Macrobrachium rosenbergii* (Table 2; also see AQD Annual Reports 1975 to 1983). ADSEA '87, '91, and '94 called for the development of broodstocks, hatchery techniques, feeds, grow-out culture, and disease control methods. But it seems that AQD researchers already have their hands full with research on tiger shrimps and various fishes. A collaborative research program with the Australian Centre for International Agricultural Research may provide just the incentive to continue the mudcrab studies started in 1977.

Artemia has been and still is in great demand as fish food in aquaculture. AQD has collaborated with the *Artemia* Research Centre of the University of Ghent, Belgium, in the development of culture techniques for, and uses of, *Artemia* (Table 2).

Table 2. The number of publications by AQD researchers on various topics concerning crustaceans other than tiger shrimp.

Species / Research topics	Number of papers 1976-1980	1981-1987	1988-1991	1992-1994	Total
Scylla serrata					
Disease	1				1
Grow-out economics			1	1	2
Penaeus japonicus					
Life cycle			1		1
Feeding	3				3
Penaeus indicus					
Spawning		2	2		4
Larval development		1			1
Penaeus merguiensis					
Larval development	1				1
Parasites	1	2			3
Macrobrachium rosenbergii					
Grow-out		1			1
Diseases		1			1
Artemia salina	4	5	1	1	11

Research on Milkfish

AQD's research program on milkfish also started with induced spawning of wild adults, simultaneous with studies on the life history and ecology of the species, and the economics of the milkfish industry (Librero et al. 1976, Vanstone et al. 1977, Chaudhuri et al. 1978, Liao et al. 1979, Kumagai and Bagarinao 1979, Senta et al. 1980, Smith 1981). In the early 1980s, studies were started on nutrition and feed development, and on diseases and tolerance to toxicants (Table 3). Following the spontaneous spawning of milkfish broodstock in floating cages starting in 1980 (Lacanilao and Marte 1980, Marte and Lacanilao 1986), hatchery operations became possible and larval rearing techniques were developed over the years.

The 1983 milkfish conference recommended various studies in (1) induction of gonad maturation and spawning, (2) nutrition and feed development, (3) environmental physiology and fish health, (4) fry collection and handling, (5) culture methods, and (6) economics of the industry. Much work was done and published in research areas 1, 2, and 3 but not in the others (Table 3). Studies in milkfish grow-out techniques and economics were conducted at AQD in the early 1980s but only a few of these were published and only much later (e.g., Baliao et al. 1987, Agbayani et al. 1989).

Table 3. The number of publications by AQD researchers on various research topics concerning milkfish.

Research topics	Number of papers					Total
	1976-1980	1981-1984	1985-1987	1988-1991	1992-1994	
Broodstock management		1	1	2	2	6
Endocrinology		1	2	1	3	7
Spawning	5	1	6	2	2	16
Hatchery			3	4	1	8
Larval development			3	1		4
Fry collection, storage	3	1	4			8
Nursery	1		4	3		8
Grow-out		1	1	9	1	12
Nutrient requirements	1	1	3	4	4	13
Digestive physiology		4	11	3	2	20
Feed development			1	3	1	5
Diseases, parasites	1	2	5	1		9
Tolerance limits		3	2	3	3	11
Biology	2				1	3
Ecology	4	3	4	1		12
Genetics		1		2		3
Total	17	19	50	39	20	146

Studies on fry collection were discontinued when it was more or less decided that the indigenous technology was already highly developed. Also, efficient collection techniques contribute to depletion of fishery resources - billions of larvae and juveniles of other fishes and crustaceans are captured with milkfish but these are killed either incidentally or intentionally. The 1983 conference recommended that the various species that occur with milkfish larvae be used in aquaculture where possible. One study was done to identify these other species (Bagarinao and Taki 1986), but this was not followed up.

ADSEA '87 placed milkfish No. 7 among the priority marine and brackishwater fishes for research by AQD, behind sea bass, grouper, red snapper, golden snapper, mullet, and rabbitfish. The recommendations for milkfish were to (1) refine broodstock management, (2) assess the economics of hatchery systems, (3) develop practical diets for the different life stages or phases of culture, and (4) develop methods of disease prevention and control. Diseases have not been much of a problem in milkfish, but active research was conducted and is continuing in the first three areas (Table 3).

Sometime in the late 1980s, there grew a perception that brackishwater pond culture was responsible in large part for the loss of mangroves (and for social inequities) in the Philippines and thus should not be further expanded or promoted. There was a retreat from pond studies and AQD

closed down its pond culture station in Leganes in 1990. The idea was that AQD should focus on research, such as in seed production and nutrition, that could not be easily done by the private sector, and then conduct pond studies in collaboration with private pond owners or with fisheries schools that have ponds. AQD has successfully carried out some studies with the University of the Philippines in the Visayas and with the Department of Agriculture in Iloilo, but has to strengthen its ties with the local pond operators to be able to implement the research imperatives of ADSEA'91 and '94.

Milkfish was ranked No. 2 priority by ADSEA '91. In addition to those of ADSEA '87, a few more imperatives were added. As abnormalities were found among hatchery-reared milkfish, priority was placed on the refinement of breeding and larval rearing techniques and on the assessment of the performance of hatchery larvae in grow-out systems. Studies on the bioenergetics of milkfish and on the nutrient cycles in ponds were also called for. The Representative of Japan asked AQD to study the population genetics (races and stocks) of milkfish, and the factors affecting recruitment and survival in the wild, sort of a continuation of the ecological research at AQD in the early years. A recent review paper put together the existing information on milkfish genetics and life history (Bagarinao 1994b) and can serve as a springboard for future studies.

Milkfish became No. 1 priority species after ADSEA '94 (see Priorities and Recommendations). Emphasis continues for broodstock development and management, and for hatchery refinement and economic assessment. Feeds and diseases no longer appear on the research agenda, but genetics does. Milkfish pond culture has again become a concern for research, particularly the grow-out of hatchery-bred fish, eradication of snail pests, survey and improvement of culture techniques, bioenergetics and nutrient cycles, and integrated farming. AQD has entered into a Memorandum of Understanding with the University of the Philippines in the Visayas to collaborate on pond studies. Although AQD does not favor conversion of mangrove areas to new ponds, it recognizes that brackishwater pond culture is an important reality in the Philippines, Indonesia, Thailand, and other parts of southeast Asia.

Research on Rabbitfishes and Mullets

AQD studied other herbivorous brackishwater and marine fishes in order to diversify southeast Asian aquaculture. In 1980, trials were made in the spawning and larval rearing of the mullet *Mugil cephalus* at AQD (MN Duray, personal communication). The mullet project did not get off the ground and only one paper ever came out (Baticados and Quinitio 1984). Likewise, AQD started in 1981 a research program on *Siganus* in the wake of Lam's (1972) review and the later studies on rabbitfish biology and culture. Work on spawning and larval development (Avila 1984, Juario et al. 1985, Bagarinao 1986, Duray 1986, Hara et al. 1986a) eventually produced a hatchery technology for *S. guttatus* (Hara et al. 1986b).

Unfortunately, the pond operators in the Philippines are not much interested in rabbitfishes and mullets. It seems that the market for these fishes is limited and there is not much profit incentive to develop the grow-out technology. ADSEA '87 ranked mullet No. 5 and rabbitfish No. 6 priorities among the marine and brackishwater fishes for AQD research. The development of hatchery techniques, feeds, and disease control methods were called for. During 1988-91, AQD continued research on rabbitfish spawning, larval physiology, hatchery techniques,

and feed development (Table 4). AQD maintained broodstocks of *Mugil cephalus* but otherwise did not do any prescribed research on mullet.

Table 4. Number of publications by AQD researchers on various topics concerning rabbitfishes, mullets, sea bass, groupers, snappers.

Species / Research topics	Number of papers 1984-1987	1988-1991	1992-1994	Total
Siganus guttatus				
Spawning	2	2	1	5
Hatchery	4	2		6
Larval physiology	5	2	2	9
Feed development		2		2
Mugil cephalus				
Parasite	1			1
Lates calcarifer				
Spawning	2	8	1	11
Hatchery		4		4
Larval development	4	1	1	6
Nursery		1	5	6
Nutrient requirements		1		1
Feed development		2		2
Epinephelus coioides				
Spawning	1		1	2
Sex inversion			2	2
Hatchery		2		2
Grow-out		2		2
Disease			1	1
Lutjanus argentimaculatus				
Spawning			1	1
Inventory			1	1

Similar research needs were identified during ADSEA '91, but with clear imperatives to develop broodstocks and grow-out culture techniques. Also called for were the inventory, taxonomy, and screening of rabbitfishes and mullets suitable for culture. For rabbitfishes, the following were to be assessed: natural stocks, markets, socioeconomics of the industry, and feasibility of searanching. Only three papers on rabbitfish came out after ADSEA'91. AQD does not have the manpower to address the research gaps in the biology and culture of rabbitfishes and mullets when these are low in priority. Even when AQD acknowledges that it is a good idea to develop the aquaculture of herbivorous fishes, some sort of 'market forces' drive even the type of research that gets undertaken.

Thankfully, the expectations for rabbitfishes and mullets have been scaled down during ADSEA '94 (see Priorities and Recommendations). It remains to be seen whether even these studies could be conducted in the next few years.

Studies on Sea Bass, Groupers, and Snappers

The sea bass *Lates calcarifer,* groupers *Epinephelus* spp., and snappers *Lutjanus* spp. are now increasingly produced by aquaculture throughout most of southeast Asia. Seed production techniques were easily developed for sea bass (NICA 1986) and are in the making for groupers and snappers (Doi et al. 1991, Doi and Singhagraiwan 1993, MN Duray, personal communication). The earliest AQD research on sea bass and grouper were on spawning and larval rearing (Harvey et al. 1985, Bagarinao and Kungvankij 1986, Kungvankij et al. 1986).

ADSEA '87 ranked sea bass, grouper, and red snapper as priority species 1-3. Hatchery techniques, feeds, and disease control were the major needs to be addressed for grouper and snappers, but hatchery techniques were no longer a problem for sea bass. The papers that came out of AQD following ADSEA '87 were mostly on sea bass spawning, hatchery, and feed development; only a few papers were on grouper hatchery and grow-out (Table 4).

Grouper rose to No. 1 priority, snapper No. 3, and sea bass No. 4 after ADSEA '91. Among the recommended studies on groupers and snappers were: (1) inventory and taxonomy, for identification of species suitable for aquaculture, (2) development of broodstock and breeding techniques, (3) culture techniques in the hatchery, nursery, and grow-out, (4) feed development, and (5) health management. Studies on sex inversion among protogynous groupers were also deemed a priority. Sea bass research was to focus on induction of off-season spawning, broodstock management to control sex inversion, feed development, health management, refinement of hatchery, nursery, and grow-out techniques, and on economics and marketing. The papers after ADSEA '91 were on sea bass spawning and nursery; grouper spawning, sex inversion, and disease; and red snapper inventory and spawning (Table 4).

Perhaps the major doubt raised about the development of grouper, snapper, and sea bass culture is the carnivorous nature of these species, and thus the need for 'trash' fish, or fish meal for high-protein diets, for the nursery, grow-out and broodstock phases. This constraint is more serious for less developed countries such as the Philippines where there is no such thing as 'trash' fish and even small fish are eaten by people living along the coasts. Because culture of these species is capital-intensive, it can only be done by a few moneyed concerns and the profits accrue only to a few. Still, cage culture of these species is well established in most of southeast Asia and AQD is mandated to address the research needs.

ADSEA '94 recommends research on broodstock development and breeding, hatchery rearing, grow-out culture, feed development, and health management for grouper, snapper, and seabass, in that order. AQD will focus mostly on the seed production of groupers and snappers during the next few years.

Research on Tilapias

The aquaculture of Nile tilapia, particularly intensive cage culture with feeding, quickly became established in southeast Asia during the 1980s. AQD established its freshwater aquaculture

station in Binangonan in Laguna de Bay in 1978 and the earliest research were on tilapia breeding (Annual Reports 1978 to 1980) and feeding and nutrition (Pantastico and Baldia 1979, Santiago et al. 1982). More papers mostly on cage culture and nutrition and feeds came out between 1982 and 1987 (Table 5). ADSEA '87 placed red tilapia as No. 1 priority and other tilapias as No. 4 among freshwater Fishes for AQD research. The recommended studies were to select strains, refine hatchery techniques, and develop feeds for nursery and grow-out. The papers that came out in 1988-1991 answered these imperatives but for Nile tilapia (Table 5).

Table 5. The number of publications by AQD researchers on various research topics concerning tilapia, bighead carp, and catfish. The Binangonan Freshwater Station of SEAFDEC AQD was established in 1978.

Species / Research topics	Number of papers				
	1979-1983	1984-1987	1988-1991	1992-1994	Total
Oreochromis niloticus					
Genetics		2	3	2	7
Hatchery	1	1	3		5
Grow-out		5	3		8
Nutrient requirements	2		2	2	6
Feeding	2	3	4	1	10
Salinity tolerance				2	2
Diseases		3			3
Pollution				3	3
O. mossambicus					
Feeding	1				1
Chemical use			1		1
Red tilapia					
Feeding			1		1
Aristichthys nobilis					
Spawning			4		4
Hatchery		2	4		6
Nutrient requirements			2		2
Clarias macrocephalus					
Spawning			1	2	3
Hatchery			1		1

Nile tilapia became top priority and red tilapia No. 4 after ADSEA '91. Selective breeding was considered important for both, but concern also arose about the ecological effects of new strains. As intensive cage culture and feeding caused eutrophication and fish kills in lakes, there came calls to improve feeding techniques and management, and to develop or verify tilapia culture techniques in brackish and marine waters. The papers that came out after ADSEA '91 were

on strain comparisons, broodstock nutrition, and the effect of tilapia culture on the environment (Table 5).

The ADSEA '94 priorities for tilapia research are mostly the same as before but studies on bioenergetics, health management, and sustainability of culture have also been recommended. Tilapia culture contributes considerably to the fish supply, and ways must be found to make it compatible with the environment and with other water uses.

Research on Carps and Catfishes

Carp studies at AQD began with supplemental feeding of the rohu *Labeo rohita* and common carp *Cyprinus carpio* and on spawning and culture of bighead carp *Aristichthys nobilis* and silver carp *Hypophthalmichthys molitrix* (Annual Reports 1979 to 1985, Pantastico et al. 1986, Tabbu et al. 1986). Carps were first spawned by AQD researchers in Laguna de Bay in 1983 and the juveniles were made available to fishpen and cage operators in the lake (Fermin 1988). By 1987, there were about 16 private carp hatcheries around Laguna de Bay.

ADSEA '87 considered carps (grass carp) as No. 5 priority among freshwater fishes and called for refinement of hatchery techniques. Ten AQD papers in 1988-91 were concerned with spawning, hatchery, and nutrition of bighead (Table 5). ADSEA '91 and '94 called for more studies on bighead carp: broodstock management, genetic improvement, feed development, and disease control. More research on bighead carp have yet to be finished.

ADSEA '87 ranked catfish as No. 3 priority for research; the needs were for refined hatchery techniques, feeds for nursery and grow-out, and selected breeds. A research program on the native catfish *Clarias macrocephalus* was started and papers on spawning and hatchery techniques have already come out (Table 5). ADSEA '91 and '94 considered catfish No. 2 priority and echoed the earlier recommendations, together with the development of grow-out culture techniques and genetic characterization of *C. macrocephalus.*

In addition, there has been a lot of concern about the ecological effects of the introduction and rapid establishment of the African catfish *C. gariepinus* in the Philippines. SEAFDEC AQD is expected to study and monitor these effects.

Research on Mollusks

Mollusk research at AQD started early under the Seafarming Program and 46 studies were proposed between 1975 and 1982 (Lacanilao 1983). Many of these studies were described in the Annual Reports 1977 to 1985, but only 10 publications came out between 1978 and 1987 (Table 6), starting with Yap (1978) and Young (1980).

ADSEA '87 considered the mussel *Perna viridis,* slipper oyster *Crassostrea iredalei,* cockle *Anadara* spp., and the windowpane oyster *Placuna placenta* as top priorities for research. The R&D needed for these species were similar: resource assessment, spatfall forecast, evaluation and refinement of grow-out techniques, transplantation, depuration, product development, and hatchery techniques. ADSEA '91 produced an even more ambitious list of research topics for priority mollusks (ten species). Between 1988 and 1994, socioeconomic studies on oyster and

mussel farming were conducted, mussels were tested as biofilter in shrimp ponds, and the windowpane oyster and the donkey-ear abalone *Haliotis asinina* were spawned in the laboratory. Otherwise, AQD researchers were focused on fishes and shrimps.

The abalone has been placed top priority by ADSEA '94. Resource assessment, refinement of hatchery techniques, and development of grow-out techniques are called for. Indeed, AQD should shift more effort into mollusk research as mollusk mariculture can be profitably carried out by small-scale fishermen and has less adverse effects on the environment.

Table 6. The number of publications by AQD researchers on topics concerning mollusks and seaweeds.

Species / Research topics	Number of papers 1978-1983	1984-1987	1988-1991	1992-1994	Total
Perna viridis					
Modiolus metcalfei					
Fanning			1		1
Biology	1	1			2
Depuration		1			1
Red tide		1			1
Crassostrea iredalei					
Fanning		1			1
Biology		2			2
Sanitation		2	1		3
Placuna placenta					
Biology	1				1
Broodstock				2	2
Haliotis asinina					
Spawning				1	1
Gracilaria					
Biology				1	1
Natural stocks			1	2	3
Farming			1	2	3
Agar				7	7
Disease				1	1
Kappaphycus					
Fanning				2	2

Research on Seaweeds

AQD set up a Mollusk and Seaweed Program in 1983 but few studies were initiated. Seaweeds (*Gracilaria, Porphyra,* and *Eucheuma*) were recommended for research by ADSEA '87, and AQD responded by promptly organizing a seaweed team. ADSEA '91 placed *Eucheuma* and *Gracilaria* as the top two of five priority species. Most AQD research was on *Gracilaria* farming and agar characterization (Table 6). This focus is correct because the *Gracilaria* industry is still undeveloped and agar is more versatile and potentially more profitable than carageenan from *Eucheuma.* ADSEA '94 called for more studies on *Gracilaria* and *Kappaphycus* (see Priorities and Recommendations).

Research on 'Non-Commodities'

Table 7 shows the number of AQD publications about non-commodity topics and those that bear on environmental issues. Many studies on the limnology, biology, and socioeconomics of Laguna de Bay and other lakes in the Philippines were described in Annual Reports 1977 to 1982, and others on aquaculture engineering in Annual Reports 1980 and 1982. AQD has the potential to carry out more studies of the environmental type: biodiversity conservation, pollution, socioeconomics, and sustainable culture techniques. Environmental studies in aquaculture were not officially recommended by ADSEA '87 and ADSEA '91, but a few such studies were carried out by AQD (e.g., Cuvin-Aralar 1990, Santiago and Arcilla 1993). ADSEA '94 recommended many such studies, but it remains for the AQD researchers to include environmental concepts in their mainstream (breed, seed, feed, diseases, production) studies.

Table 7. Number of publications of AQD researchers on 'non-commodity' topics.

Research topics	Number of papers				Total
	1976-1980	1981-1987	1988-1991	1992-1994	
Taxonomy	6	6		1	13
Fishing gears	1	2			3
Natural food	1	4	6	1	12
Aquaculture engineering		8			8
Mangroves		1	1	3	5
Polyculture		5	2		7
Red tide		3			3
Epizootic ulcerative syndrome		1		1	2
Laguna de Bay		1	1	1	3
Heavy metals			5	3	8
Algae in wastewater		2			2
Socioeconomics				2	2

AQD's Contribution to Aquaculture Development

AQD has filled some of the information gaps in southeast Asian aquaculture, as shown in the previous section, but still has to address many more. AQD's major contributions so far have been the technologies for tiger shrimp seed production, grow-out culture, feeds, and disease diagnosis; milkfish seed production and feeds; rabbitfish seed production; and tilapia feeds. In recent years, the advances AQD made in milkfish seed production have apparently been overtaken by Taiwan and Indonesia, which both now have well established milkfish hatcheries run by the private sector (Liao 1993, Ahmad 1993, S Kumagai, personal communication).

AQD's training program has been going since 1974 and has produced a large number of technical personnel who have gone into the aquaculture business by themselves or have helped direct further aquaculture R&D by their governments (Primavera 1988, Villegas et al. 1993, Villegas 1995). AQD has also developed its own research manpower over the years, having sent most of its staff for graduate studies. These new Ph.D. holders have taken over the AQD research leadership from the pioneer administrators.

AQD in Context

AQD's research accomplishments must be viewed in context, in relation to the development of aquaculture in southeast Asia and Japan. AQD was established in 1973, quite recently by many standards. Brackishwater pond culture in the Philippines and Indonesia started probably four centuries ago, mariculture in Japan about ten centuries ago, and freshwater fish culture in China as early as 3,000 years ago (Herre and Mendoza 1929, Lin et al. 1980, Davy 1991). Earlier developments were slow and unsystematic; most advances were made during the last century and particularly after the Second World War. Most other countries in Asia also have had some form of aquaculture for a long time. For example, Malaysia started carp culture in mining pools in the 1900s, shrimp culture in ponds in the mid-1930s, and cockle culture in 1948 (Liong et al. 1988). In Thailand, sea bass has been produced from ponds for 50 years and has been artificially propagated in hatcheries and cultured in cages since 1973 (Sirikul et al. 1988). Years before the ADSEA '87 seminar-workshop recommended them for AQD research, grow-out culture systems for *Epinephelus, Lutjanus, Macrobrachium, Clarias,* and *Oxyeleotris* (marble goby) were already established in Thailand, Malaysia, and Singapore (Sirikul et al. 1988, Liong et al. 1988, Cheong 1988) and for the seaweed *Eucheuma* in the Philippines (Camacho and Macalinlag-Lagua 1988).

AQD's role in aquaculture research and development has been shared by many R&D organizations, including government agencies, universities, the International Center for Living Aquatic Resources Management, the Asian Institute of Technology, and the Network of Aquaculture Centres in Asia-Pacific. The governments and universities of most Asian countries have undertaken research to solve the technical constraints in their own aquaculture sectors. Aquaculture research has been going a long time in Japan as well as in the other Asian tiger economies (Davy 1991, Lee et al. 1993, Chou 1994).

The Communication Gap

Through the ADSEA seminar-workshops and other meetings, as well as its newsletters, extension manuals, and other publications, AQD has dutifully disseminated aquaculture

information (Villegas 1995). But there seems to be gaps between what is written, what is understood, and what is transferred and used. One 'problem' may be that AQD researchers write and lecture in English, whereas the foreign trainees, the farmers, and the other users of information are not all well versed in this language. Another may be that AQD produces extension materials based on research results, but otherwise does not have a strong hand in the on-site extension of technology, believing this to be more the function of government line agencies.

An unmistakable communication gap exists even among the participants of ADSEA. During each ADSEA, AQD researchers reviewed the advances in the biology and culture of various species. However, none of the country representatives (except those from the Philippines) related these advances (or the lack thereof) to their needs, at least not in the country papers they wrote for the three ADSEA proceedings. In addition, none of the country representatives in later ADSEAs referred to their own compatriots' country papers in earlier ADSEAs. It is as if the country representatives did not make any connection with each other, nor with the AQD researchers. There may be various reasons for this communication gap but the result is unfortunate: incomplete feedback. AQD researchers do their best to address the problems as identified by the country representatives. But the country representatives do not indicate whether their problems have been sufficiently addressed by AQD, and whether or not their research needs have actually changed from one representative to the next (or from one ADSEA to another). Obviously, the connection must be made if both AQD and the SEAFDEC Member Countries are to realize fully the goals of the ADSEA meetings, as well as AQD's mandates.

A clear example of this communication gap within the ADSEA experience is what happened to the overview papers of Rabanal (1988, 1994). In his ADSEA '87 paper, Rabanal (1988) discussed in many paragraphs the production constraints and the prospects for growth and expansion of the aquaculture industry in southeast Asia. But the official ADSEA '87 recommendations hardly reflected these constraints; Juario and Benitez (1988) published a list of recommendations in outline form — in phrases with mere keywords and without enough context — such that the recommendations probably meant slightly different directions to different researchers. Unfortunately, this outline was probably what AQD researchers consulted when they chose their research topics for the years that followed. The same constraints and others were identified again by Rabanal (1994) and again not reflected in the (unpublished) official ADSEA '91 recommendations. Similar constraints in shrimp and carp culture have still been noted by Kutty (1995) during ADSEA'94.

The communication gap is otherwise much reduced between AQD researchers and the Philippine representatives, for obvious reasons. The proximity allows the government agencies (Department of Agriculture and Department of Science and Technology), the academe (including the University of the Philippines), and the private sector in the Philippines to pick up new findings from, and report new problems to, AQD both during the ADSEA seminar-workshops and especially during the local yearly round-table discussions. These yearly discussions invite feedback and suggestions from the industry practitioners, but are often prefaced with the caveat that what AQD can do for the Philippines is limited by what has already been programmed for southeast Asia based on the previous ADSEA.

The Redirection of AQD

The Aquaculture Department of the Southeast Asian Fisheries Development Center now faces the challenge of generating innovations in aquaculture that will assure a reliable supply of animal protein, and at the same time protect the environment and improve the quality of life of marginalized farmers and fishermen. Like many other organizations worldwide, SEAFDEC AQD was a product of its time and has evolved with the changes of the times. AQD started out as a production-oriented development organization and, in response to the realities and needs of the 1990s, has turned into a research and development institution concerned with the environment and committed to sustainable aquaculture and sustainable development.

Historically, this transformation at AQD was marked by the assumption of the Office of the Chief by Dr. Flor Lacanilao in 1981-1982 and 1986-1992. He infused AQD with his ideas of aquaculture development that is environment-friendly and socially equitable, and of aquaculture research that passes peer review at the level of the international scientific community. AQD is set on continuing in this direction.

Recommendations for Aquaculture and the Environment

During ADSEA '87, Camacho and Macalinlag-Lagua (1988) recommended research on 13 topics, which were general enough to apply to southeast Asia, were well grounded in sound aquaculture (and ecological) principles, and already pointed the way towards sustainable aquaculture, even without any reference to the buzzwords from the 1987 Brundtland Report. AQD has addressed about half the recommendations (on breeding and seed production, nutrition and feed development, and disease control). But the following research needs have been mostly overlooked: grow-out technologies (aside from feeds); post-harvest handling, processing, and marketing; maintenance of environmental quality at culture sites; and stock assessment of fishery resources to complement fish dispersal activities.

Calls for environmental studies were made by the country representatives during ADSEA '87. Pollution in Johore Strait and acid sulfate soils in shrimps ponds were the problems in Malaysia (Liong et al. 1988). Singapore also reported poor water quality and plankton build-up in ponds, and water stagnation and oxygen deficiency in cage farming sites (Cheong 1988). In the Philippines, the pollution and use conflicts in Laguna de Bay made headlines, and mollusk culture suffered from environmental deterioration (red tides), displacement by housing and industry, and inadequate sanitation (Camacho and Macalinlag-Lagua 1988). Among the aquaculture problems in Japan were: (1) pollution due to use of 'trash' fish as feed, (2) red tides that badly affected yellowtail culture, (3) predators, fouling animals, oxygen deficiency, and slow growth of mollusks in culture grounds, and (4) conservation of suitable farming grounds (Mito and Fukuhara 1988).

Seafarming and Searanching

The 1991 ADSEA seminar-workshop was convened specifically to examine the prospects for Seafarming (or mariculture) and searanching in southeast Asia and Japan. The idea was that aquaculture development should move in the direction of the open seas as inland and nearshore waters have become polluted or subject to conflicting claims and uses. Of course, Japan is already way ahead in both Seafarming and searanching (Umezawa 1988) but Thailand, Singapore, and Malaysia also have well developed mariculture (Sungkasem and Tookwinas 1994, Chou 1994,

Kechik 1995). Mariculture in the Philippines produces seaweeds and mollusks on a commercial scale, and marine fish culture in cages is mostly experimental or small-scale (Delmendo 1994). Recently, milkfish pens have been set up in shallow waters in Cavite inside Manila Bay (EEC Flores, personal observation); this new development may reduce the controversial pen culture operations in the much-abused freshwater lake, Laguna de Bay.

A consensus has not been reached regarding Seafarming as a solution to some of the environmental problems of and from aquaculture. The environment-aquaculture issue is very complicated and Seafarming and searanching may themselves cause some ecological problems (Munro 1994). Sustainable development of Seafarming and searanching calls for careful planning, and investments must take into account environmental, biotechnological, and socioeconomic considerations (Chong 1994). After ADSEA '91 (and even before), some AQD research shifted towards the development of Seafarming and searanching. AQD in collaboration with the International Development Research Centre (Canada) launched in 1991 what came to be called the Community Fishery Resources Management Project. This Project included in the proposal the Seafarming of seaweeds, mollusks, and fishes, and the searanching of snappers and other reef fishes at Malalison Island (Agbayani 1995).

Sustainable and Responsible Aquaculture

The theme for ADSEA '94 was "Sustainable Aquaculture Development" and everybody seemed to have joined the bandwagon. But the reality seems to be that 'the right hand does not know what the left hand is doing.' Of course, the private sector always has pushed and will push for aquaculture development that turns a profit. But even the public sector, the academe, and AQD itself are not internally consistent about which R&D contributes to sustainable aquaculture. For example, the propagation and monoculture of a 'super strain' of fish increases the risk of total crop failure in case some 'super disease' strikes. Also, the culture of highly priced carnivorous fishes that require 'trash' fish or fish meal can not be easily justified nor considered sustainable. Such inconsistencies and the inertia involved in the redirection of R&D attest to the very real difficulties with the implementation of sustainable aquaculture.

Strategies for R&D for sustainable aquaculture were discussed during ADSEA '94. The principles of sustainability must be incorporated in all phases of the R&D, from planning to monitoring, to reporting. Sustainability issues must guide feed development and feeding management, the use of drugs and agro-chemicals, and the development of culture techniques for chosen species. Research must also address cross-commodity, multidisciplinary and multisectoral problems such as socioeconomics, marketing, equity, legislation, and policy. Research, training, and development institutions at different levels must strengthen collaborations, but divide the work and minimize duplication, to accomplish projects and solve problems more efficiently. Technology packages for small farmers, especially on environmentally compatible culture techniques, must be developed by AQD. AQD was asked to strengthen its role as extension agents of improved technologies, e.g., by continuing to provide resource persons for the extension programs of the Philippines' Bureau of Fisheries and Aquatic Resources. Information dissemination for aquaculture practitioners and the general public must be improved to promote a balanced public opinion, and must include environment education related to sustainable aquaculture.

Csavas (1995) recommends some FAO guidelines for countries and research institutions to take to achieve sustainable and responsible aquaculture. We strongly urge that these recommendations (pages 10-11) be seriously considered when planning, implementing, and managing aquaculture R&D or enterprises.

Conclusion

In the future, AQD's regular meetings with representatives of the aquaculture sectors in southeast Asia must work at better communication and two-way feedback. These extramural consultations must be followed (or preceded) by intramural discussions not only of research results, but of concepts and new directions. AQD must continue to shift some of its resources to more research in sustainable fanning systems and environmental problems in aquaculture.

This review paper and the ADSEA '94 proceedings add more to the voluminous stacks already published by national and international organizations on research directions, priorities, coordination, collaboration, and information dissemination in aquaculture development, which now highlight environmental concerns, social equity, and gender issues. Aquaculture and fisheries gatherings in the future should not merely echo what had been said and written before, but really work on concrete measures to address the issues and concerns already raised. Large congresses, such as the Asian Fisheries Forum held every three years, often hold small-group workshops or symposia. These groups can be directed to work on specific issues and come up with concrete action programs to be implemented by specified organizations. Such action programs are a better output of meetings than printed proceedings!

AQD will encourage and organize small-group meetings of aquaculture scientists, practitioners, and government representatives to tackle specific problems and implement specific solutions. A small meeting in November 1995 is being organized by SEAFDEC AQD and the Food and Agriculture Organization to address the problem of chemical abuse in aquaculture.

Let us all stop talking and start concretizing sustainable and responsible aquaculture. The next ADSEA should, hopefully, be an occasion for comparing success stories.

References

Agbayani RF. 1995. Community fishery resources management in Malalison Island, Philippines, pp. 209-219. In: Bagarinao and Flores (1995) below.

Agbayani RF, Baliao DD, Franco NM, Ticar RB, Guanzon NG Jr. 1989. An economic analysis of the modular pond system of milkfish production in the Philippines. Aquaculture 83: 249-259.

Ahmad T. 1993. Support of research on milkfish (*Chanos chanos* Forskal) for fishery development. Indonesian Agricultural Research Development Journal 15 (1): 10-15.

Aiken D. 1992. The perils of accountability in science. World Aquacult. 23(3): 2.

Avila EM. 1984. Hormone-induced spawning and embryonic development of the rabbitfish *Siganus vermiculatus* (Pisces: Siganidae). Philipp. Scient. 21: 75-108.

Bagarinao T. 1986. Yolk resorption, onset of feeding and survival potential of larvae of three tropical marine fish species reared in the hatchery. Mar. Biol. 91: 449-459.

Bagarinao T. 1994a. On publishing scientific papers in peer-reviewed /5/-covered journals. Philipp. Scient. 31.

Bagarinao T. 1994b. Systematics, distribution, genetics, and life history of milkfish *Chanos chanos.* Env. Biol. Fish. 39: 23-41.

Bagarinao T, Kungvankij P. 1986. An incidence of swimbladder stress syndrome in hatchery-reared sea bass (*Lates calcarifer*). Aquaculture 51: 181-188.

Bagarinao T, Taki Y. 1986. The larval and juvenile fish community in Pandan Bay, Panay Island, Philippines, pp. 728-739. In: Uyeno T, Arai R, Taniuchi T, Matsuura K (eds) Indo-Pacific Fish Biology. Ichthyological Society of Japan, Tokyo.

Bagarinao TU, Flores EEC (eds). 1995. Towards Sustainable Aquaculture in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines, 254 pp.

Baliao DD, Franco NM, Agbayani RF. 1987. The economics of retarding milkfish growth for fingerling production in brackishwater ponds. Aquaculture 62: 195-205.

Baticados MCL, Quinitio GF. 1984. Occurrence and pathology of an *Amyloodinium-like* protozoan parasite on gills of grey mullet, *Mugil cephalus.* Helgolander Meeresunters. 37: 595-601.

Camacho AS, Macalinlag-Lagua N. 1988. The Philippine aquaculture industry, pp. 91-116. In: Juario and Benitez (1988) below.

Chaudhuri H, Juario JV, Primavera JH, Samson R, Mateo R. 1978. Observations on the artificial fertilization of eggs and the embryonic and larval development of milkfish *Chanos chanos* (Forskal). Aquaculture 13: 95-113.

Cheong L. 1988. Aquaculture development in Singapore, pp. 117-128. In: Juario and Benitez (1988) below.

Chong KC. 1994. Economic and social considerations in seafarming and searanching, pp. 152-159. In: Lacanilao et al. (1994) below.

Chou R. 1994. Seafarming and searanching in Singapore, pp. 115-121. In: Lacanilao et al. (1994) below.

Chua TE. 1993. Environmental management of coastal aquaculture development, pp. 199-212. In: Pullin RSV, Rosenthal H, Maclean JL (eds) Environment and Aquaculture in Developing Countries. International Center for Living Aquatic Resources Management, Manila; Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn.

Csavas I. 1995. Recommendations for responsible aquaculture, pp. 1-12. In: Bagarinao and Flores (1995) above.

Cuvin-Aralar MLA. 1990. Mercury levels in the sediment, water, and selected finfishes of Laguna Lake, the Philippines. Aquaculture 84: 277-288.

Davy FB. 1991. Mariculture Research and Development in Japan. An Evolutionary Review. International Development Research Centre, Ottawa, 97 pp.

de la Cruz CR. 1995. Brackishwater integrated farming systems in southeast Asia, pp. 23-36. In: Bagarinao and Flores (1995) above.

Delmendo MN. 1994. Seafarming and searanching development in the Philippines, pp. 105-114. In: Lacanilao et al. (1994) below.

Doi M, Singhagraiwan T. 1993. Biology and Culture of Red Snapper, *Lutjanus argentimaculatus.* The Research Project of Fishery Resource Development of the Kingdom of Thailand, Rayong, 51 pp.

Doi M, Munir MN, Nik Razali NL, Zulkifli T. 1991. Artificial Propagation of the Grouper *Epinephelus suillus* at the Marine Finfish Hatchery in Tanjong Demong, Terengganu, Malaysia. Department of Fisheries, Ministry of Agriculture Malaysia, Kuala Lumpur, 41 pp.

Duray MN. 1986. Biological evaluation of three phytoplankton species (*Chlorella* sp., *Tetraselmis* sp., *Isochrysis galbana)* and two zooplankton species (*Crassostrea iredalei, Brachionus plicatilis)* as food for the first-feeding *Siganus guttatus* larvae. Philpp. Scient. 23: 41-49.

Fermin AC. 1988. Broodstock management and seed production of tilapia and carp, pp. 211-230. In: Juario and Benitez (1988) below.

GESAMP. 1991. Reducing Environmental Impacts of Coastal Aquaculture. Joint Group of Experts on the Scientific Aspects of Marine Pollution, Reports and Studies No. 47, 35 pp. Food and Agriculture Organization, Rome.

Hara S, Kohno H, Taki Y. 1986a. Spawning behavior and early life history of the rabbitfish, *Siganus guttatus,* in the laboratory. Aquaculture 59: 273-285.

Hara S, Duray MN, Parazo M, Taki Y. 1986b. Year-round spawning and seed production of the rabbitfish, *Siganus guttatus.* Aquaculture 59: 259-272.

Harvey B, Nacario J, Crim LW, Juario JV, Marte CL. 1985. Induced spawning of sea bass *Lates calcarifer* and rabbitfish *Siganus guttatus,* after implantation of pelleted LH-RH analogue. Aquaculture 47: 53-59.

Herre AW, Mendoza J. 1929. Bangos culture in the Philippine Islands. Philipp. J. Sci. 38: 451-509.

Juario JV, Benitez LV (eds). 1988. Perspectives in Aquaculture Development in Southeast Asia and Japan. SEAFDEC Aquaculture Department, Iloilo, Philippines, 316 pp.

Juario JV, Ferraris RP, Benitez LV (eds). 1984. Advances in Milkfish Biology and Culture. SEAFDEC Aquaculture Department, Iloilo, Philippines,

Juario JV, Duray MN, Duray VM, Nacario JF, Almendras JME. 1985. Breeding and larval rearing of the rabbitfish *Siganus guttatus* (Bloch). Aquaculture 44: 91-101.

Kechik IA. 1995. Aquaculture in Malaysia, pp. 125-135. In: Bagarinao and Flores (1995) above.

Kumagai S, Bagarinao T. 1979. Results of drift card experiments and considerations on the movement of milkfish eggs and larvae in the northern Sulu Sea. Fish. Res. J. Philipp. 4: 64-81.

Kungvankij P. Tiro LB Jr, Pudadera BP, Potestas IO. 1986. Induced spawning and larval rearing of grouper (*Epinephelus salmoides* Maxwell), pp. 663-666. In: Maclean et al. (1986) below.

Kutty MN. 1995. Aquaculture development and sustainability in southeast Asia, pp. 91-108. In: Bagarinao and Flores (1995) above.

Lacanilao FJ. 1983. A Review of the Research Activities of the SEAFDEC Aquaculture Department. Special Publication No. 8, 132 pp. The Secretariat, Southeast Asian Fisheries Development Center, Bangkok.

Lacanilao F, Marte C. 1980. Sexual maturation of milkfish in floating cages. Asian Aquaculture 3(8): 4, 6.

Lacanilao F, Coloso RM, Quinitio GF (eds). 1994. Aquaculture Development in Southeast Asia and Japan and Prospects for Seafarming and Searanching. SEAFDEC Aquaculture Department, Iloilo, Philippines, 159 pp.

Lam TJ. 1974. Siganids: their biology and mariculture potential. Aquaculture 3: 325-354.

Lee CS, Su MS, Liao IC (eds). 1993. Finfish Hatchery in Asia. TML Conference Proceedings No. 3, 252 pp. Taiwan Fisheries Research Institute, Taipei.

Liao IC. 1993. Finfish hatcheries in Taiwan: recent advances, pp. 1-25. In: Lee et al. (1993) above.

Liao IC, Juario JV, Kumagai S, Nakajima H, Natividad M, Buri P. 1979. Induced spawning and larval rearing of milkfish *Chanos chanos* (Forsskal). Aquaculture 18: 75-93.

Librero AR, Nicolas ES, Vasquez EO, Nazarena AM. 1976. An assessment of the fishpond technology and management of milkfish (bangos) in the Philippines. Research Paper Series No. 4, 143 pp + Annex 40 pp. SEAFDEC Aquaculture Department, Iloilo; Philippine Council for Agriculture and Resources Research, Los Baños.

Lin Z, Chao JZ, Zeng MD, Hai O, Chen FC, Li YG, Zhao ZL, Su ZF. 1980. Pond Fish Culture in China. Pearl River Fisheries Research Institute, Guangzhou, China, 136 pp.

Liong PC, Hanafi HB, Merican ZO, Nagaraj G. 1988. Aquaculture development in Malaysia, pp. 73-90. In: Juario and Benitez (1988) above.

Marte CL, Lacanilao FJ. 1986. Spontaneous maturation and spawning of milkfish in floating cages. Aquaculture 53: 115-132.

Maclean JL, Dizon LB, Hosillos LV (eds). 1986. The First Asian Fisheries Forum. Asian Fisheries Society, Manila, 727 pp.

McManus JW. 1995. Coastal fisheries and mollusk and seaweed culture in southeast Asia: integrated planning and precautions, pp. 13-22. In: Bagarinao and Flores (1995) above.

Mito S, Fukuhara O. 1988. Aquaculture development in Japan, pp. 39-71. In: Juario and Benitez (1988) above.

Motoh H. 1985. Biology and ecology of *Penaeus monodon,* pp. 27-36. In: Taki et al. (1985) below.

Munro JL. 1994. Ecological impacts of seafarming and searanching, pp. 145-151. In: Lacanilao et al. (1994) above.

NICA. 1986. Technical Manual for Seed Production of Sea Bass. National Institute for Coastal Aquaculture, Songkhla, Thailand, 49 pp.

Pantastico JB, Baldia JP. 1979. Supplemental feeding of *Tilapia mossambica,* pp. 587-593. In: Halver JE, Tiews K (eds) Finfish Nutrition and Fishfeed Technology Vol. 1. Heenemann Verlag Gesselschaft mbH, Berlin.

Pantastico JB, Baldia SF, Baldia JP. 1986. Efficiency of some cyanophytes as larval feed of silver carp (*Hypophthalmichthys molitrix*) and culture of *Spirulina platensis,* pp. 609-614. In: Maclean et al. (1986) above.

Phillips MJ. 1995. Shrimp culture and the environment, pp. 37-62. In: Bagarinao and Flores (1995) above.

Primavera JH. 1978. Induced maturation and spawning in five-month old *Penaeus monodon* Fabricius by eyestalk ablation. Aquaculture 13: 355-359.

Primavera JH. 1988. Training programs of SEAFDEC Aquaculture Department, pp. 293-301. In: Juario and Benitez (1988) above.

Primavera JH. 1993. A critical review of shrimp pond culture in the Philippines. Rev. Fish. Sci. 1: 151-201.

Pullin RSV. 1993. Discussions and recommendations on aquaculture and the environment in developing countries, pp. 312-338. In: Pullin RSV, Rosenthal H, Maclean JL (eds) Environment and Aquaculture in Developing Countries. International Center for Living Aquatic Resources Management, Manila; Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn.

Rabanal HR. 1988. Development of aquaculture industry in southeast Asia: an overview, pp. 3-37. In: Juario and Benitez (1988) above.

Rabanal HR. 1994. Overview of aquaculture development in southeast Asia, pp. 53-67. In: Lacanilao et al. (1994) above.

Santiago AC Jr. 1977. Successful spawning of cultured *Penaeus monodon* (Fabricius) after eyestalk ablation. Aquaculture 11: 185-196.

Santiago AE, Arcilla RP. 1993. Tilapia cage culture and the dissolved oxygen trends in Sampaloc Lake, the Philippines. Environ. Monit. Assess. 24: 243-255.

Senta T, Kumagai S, Castillo N. 1980. Occurrence of milkfish *Chanos chanos* (Forsskal) eggs around Panay Island, Philippines. Bulletin Faculty of Fisheries Nagasaki University 48: 1-11.

Sirikul B, Luanprida S, Chaiyakam K, Sriprasert R. 1988. Aquaculture development in Thailand, pp. 129-148. In: Juario and Benitez (1988) above.

Smith IR. 1981. The Economics of the Milkfish Fry and Fingerling Industry of the Philippines. ICLARM Technical Reports 1, 146 pp. International Center for Living Aquatic Resources Management, Manila; SEAFDEC Aquaculture Department, Iloilo, Philippines.

Sungkasem P, Tookwinas S. 1994. Seafarming and searanching in Thailand, pp. 122-128. In: Lacanilao et al. (1994) above.

Tabbu M, Lijauco M, Eguia R, Espegadera C. 1986. Polyculture of bighead carp, common carp, and Nile tilapia in cages in Laguna Lake. Fish. Res. J. Philipp. 11(1-2): 13-20.

Taki Y, Primavera JH, Llobrera JA (eds). 1995. Proceedings of the First International Conference on the Culture of Penaeid Prawns/Shrimps. SEAFDEC Aquaculture Department, Iloilo, Philippines, 197 pp.

Umezawa S. 1994. Overview of seafarming and searanching technology in Japan, pp. 93-104. In: Lacanilao et al. (1994) above.

Vanstone WE, Tiro LBJr, Villaluz AC, Ramsingh DC, Kumagai S, Duldoco PJ, Barnes MML, Dueñas CE. 1977. Breeding and larval rearing of the milkfish *Chanos chanos* (Pisces: Chanidae), pp. 3-17. In: Induced Spawning, Artificial Fertilization of Eggs, and Larval Rearing of the Milkfish *Chanos chanos* (Forskal) in the Philippines. Technical Report No. 3. SEAFDEC Aquaculture Department, Iloilo, Philippines.

Villegas CT. 1995. Training and information dissemination at the SEAFDEC Aquaculture Department, pp. 221-225. In: Bagarinao and Flores (1995) above.

Villegas CT, Castanos MT, Lacierda RB (eds). 1993. Proceedings of the Aquaculture Workshop for SEAFDEC/AQD Training Alumni, 8-11 Sep 1992. SEAFDEC Aquaculture Department, Iloilo, Philippines, 173 pp.

Yap WG. 1978. Settlement preferences of the brown mussel *Modiolus metcalfei* Hanley and its implication on the aquaculture potential of the species. Fish. Res. J. Philipp. 3(1): 65-70.

Young A. 1980. Larval and postlarval development of the windowpane shell *Placuna placenta* L. (Bivalvia: Placunidae) with a discussion on its natural settlement. Veliger 23: 141-148.